Mesquite and Cactus Abundance on a Grazed and Protected Sonoran Desert Grassland Site

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Introduction

- Woody cover has increased in rangelands worldwide over the last 150 years (Archer 2010) and on the Santa Rita Experimental Range (McClaran, 2003; Fig 1).
- In arid or semi-arid ecosystems, this replacement of grasses by xerophytic shrubs is a form of desertification that alters ecological function and reduces livestock grazing capacity.
- While livestock grazing has been traditionally regarded as a key cause of woody plant encroachment, studies seeking to verify this have had mixed results (Browning and Archer 2011).

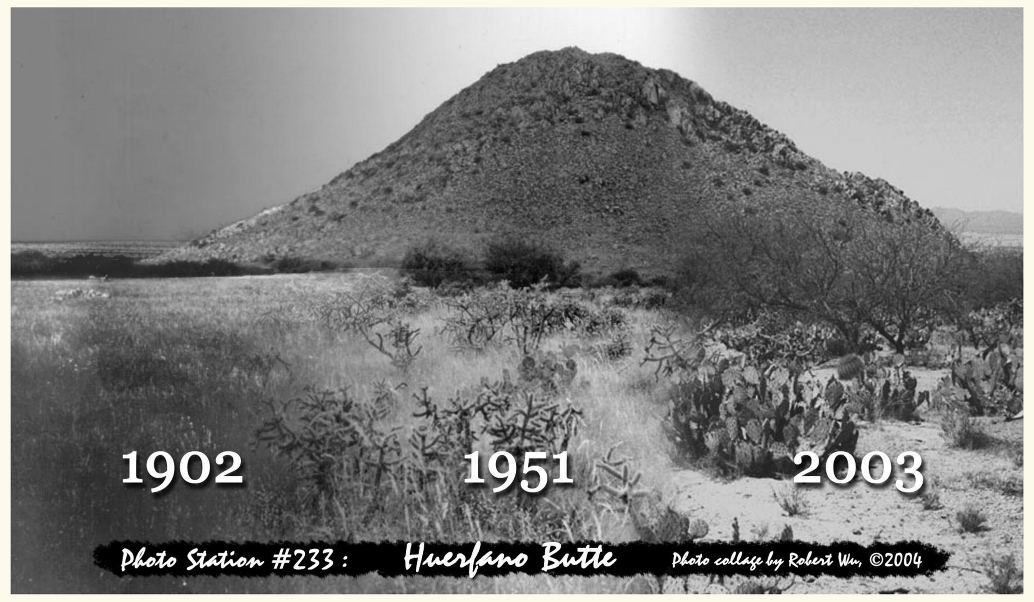

Figure 1: This composite repeat photography image displays clear increase in shrub and cactus cover on the Santa Rita Experimental Range over 100 years.

Question

Has long-term livestock grazing or protection from it differentially influenced the size and abundance of mesquite (*Prosopis velutina*) and prickly pear cactus (*Opuntia engelmannii*)?

Hypotheses

- H_1: Canopy cover and biomass of individual mesquite shrubs and prickly pear patches will be greatest on long-term grazed sites and lowest on sites with long-term protection from grazing,
- H_2: Mesquite and prickly pear density will be greater on grazed areas than on areas long protected from grazing, and
- H_3: At the stand-scale, cover and biomass of prickly pear will be greatest on grazed areas and lowest on areas protected from grazing.

Study Site

- The Santa Rita Experimental Range (SRER) in Southern Arizona (31.8139° N, -110.8886° W) was established in 1902 to promote recovery from heavy, unregulated livestock grazing. Cattle were returned to the site in 1916 at a reduced stocking rate, with a rotational grazing system implemented in 1975.
- The *Eriopoda Exclosure* (184 x 90 m; 31.83818° N,-110.843664° W; 1150 m; 300-400 mm annual PPT zone) in SRER pasture 2N (Fig 2) has excluded livestock grazing since its establishment 1925 (Mark Heitlinger, pers. comm.). The landscape including the exclosure was a gently sloping (4-5%) west-facing bajada gradient (sandy loam upland, MLRA 41-3).
- Vegetation in and around the *Eriopoda Exclosure* is a mixture of shrubs, primarily mesquite (*Prosopis velutina*), and grasses, including black grama (*Bouteloua eriopoda*) and Arizona cottontop (*Digitaria californica*).

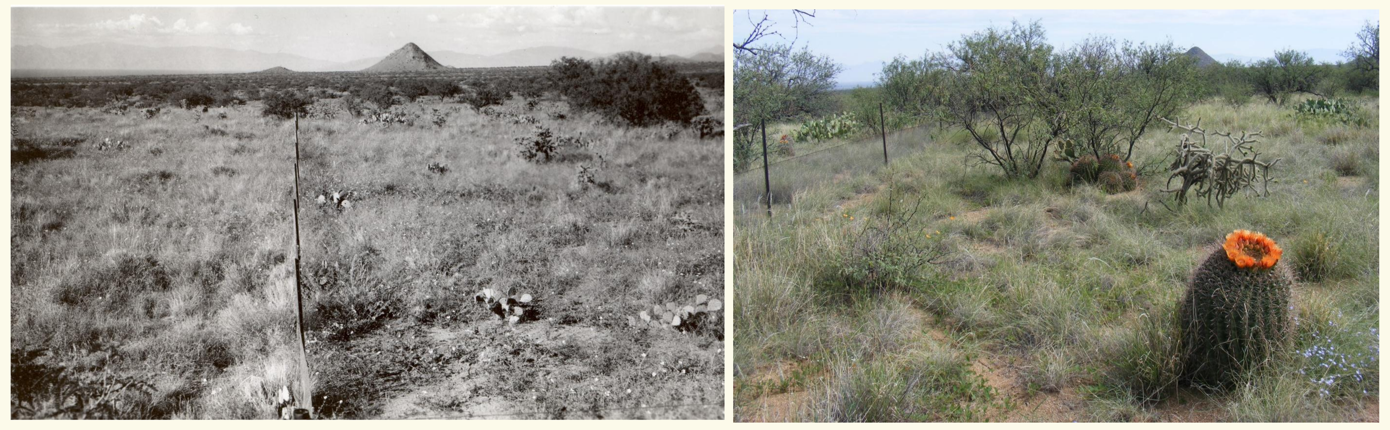

Figure 2: *Eriopoda Exclosure* in 1939 and 2013

Methods

- Vegetation was sampled in 10 m x 10 m plots, in and out of the *Eriopodia Exclosure* (n=23).
- To create plots, a grid comprised of 10x10 m cells was superimposed over Google Earth's 2012 view of the *Eriopoda Exclosure* and surroundings (Fig 3).
  - An equal number of grid cells on similar topoedaphic settings were outlined inside and outside the exclosure. Cells disturbed by a fence or the road were excluded.
  - Plots were numbered consecutively and every forth plot was designated for sampling.
  - Plot UTM coordinates on the Google Earth map were put into a handheld GPS (Garmen Etrack Legend) and used to locate plots in the field.

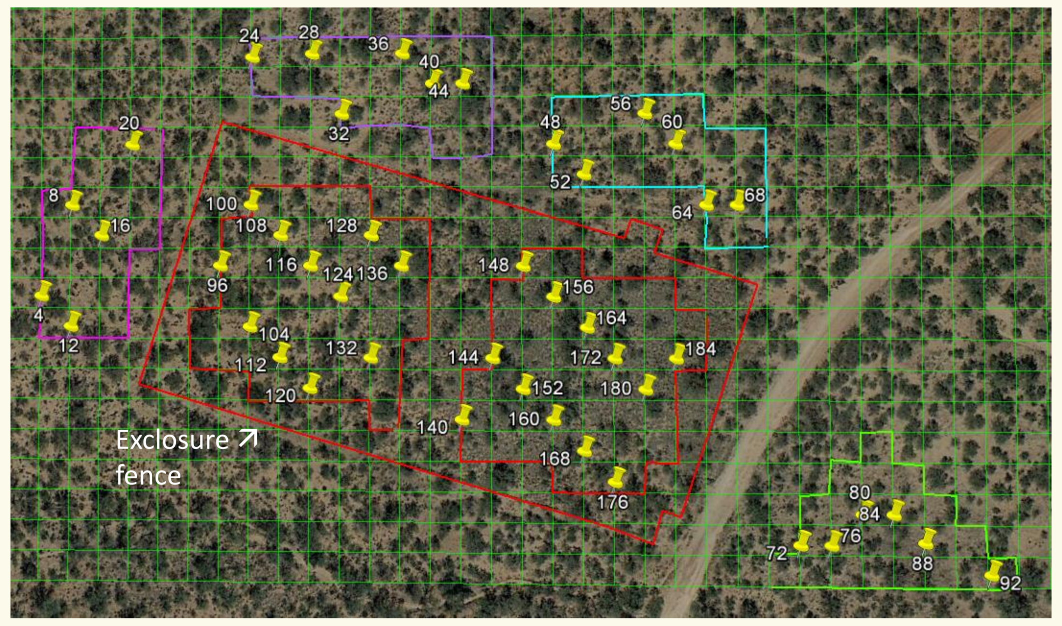

Figure 3: Grid cells over the map of the exclosure. Those with numbered pins were sampled.

- All mesquite plants > 0.40 m height and whose stems arose within the plot were inventoried. Number of live stems, stem basal diameter, canopy were recorded for each shrub.
- Plant canopy cover (CC, m^2) was estimated by measuring canopy diameter along its longest axis and its widest diameter perpendicular to the longest axis. CC was then computed as a circle:
  $CC = \pi\,(([L+W]/2)/2)^2$
- Biomass of each mesquite plant was computed from basal diameter using allometric relationships in McClaran et al. (2013).
- All prickly pear patches > 0.30 m diameter, with more than 50% of their cover inside the plot, were measured for height and canopy dimensions.
- Biomass of each prickly pear patch was computed using allometric relationships (Archer and Vogel, unpublished).
- Soil cores (5 cm dia x 50 cm depth) were collected in (n=6) and out (n=5) of the upper, middle and lower slopes of exclosure area from bare ground patches between shrubs.
- Soil cores were divided by depth into thirds, and each depth increment was analyzed for percentage by weight of particles > 2mm (sieve), carbon content (loss on ignition), carbonates (H_2SO_4 fizz test), pH (1:1 soil:water solution) and color (digital chromameter).

Soil Results

- Soil inside and outside the exclosure did not vary significantly in pH, %C, % particles >2mm, presence of carbonates, or depth to restrictive layer (Table 1).
- % particles > 2mm was significantly greater at the bottom depth (>32 cm) than at the top (0-16 cm) or middle (16-32 cm) depths.
- Other soil factors (pH, %C, presence of carbonates) did not vary significantly by depth.

Table 1: Properties of soils inside and outside the exclosure, reported as mean ± standard error. Data shown for upper depth (0-16 cm).

Parameter	Inside	Outside	P-value
pH	6.6 ± 0.1	6.5 ± 0.1	p=0.34
%C	1.1 ± 0.04	1.1 ± 0.04	p=0.84
% particles > 2mm	27.6 ± 0.9	26.7 ± 1.6	p=0.58
Presence of carbonates	None detected	None detected	------
Depth to restrictive layer	> 60 cm	> 60 cm	------
Munsell Hue	8.32YR ± 0.05YR	8.31YR ± 0.04YR	p=0.81
Munsell Value	4.04 ± 0.03	3.99 ± 0.03	p=0.15
Munsell Chroma	2.80 ± 0.03	2.84 ± 0.04	p=0.54

Vegetation Results

- Mixed models with plot specified as a random variable found no significant difference inside and outside the exclosure for mesquite biomass per plant ($F_{1,43} = 0.31$, $p = 0.6$); canopy area per plant ($F_{1,43} = 0.03$, $p = 0.9$); or prickly pear biomass per patch ($F_{1,36} = 3.29$, $p = 0.079$).

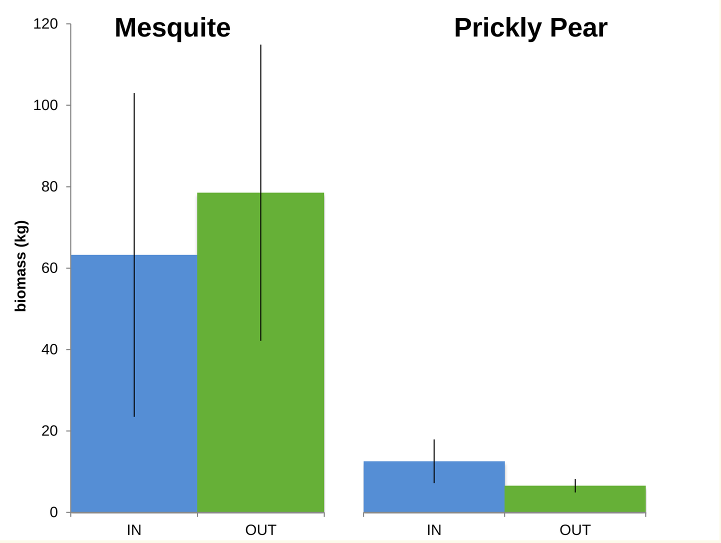

Figure 4: Mean (± SE) biomass (kg/plant or patch) was statistically comparable inside and outside the exclosure for both mesquite and prickly pear.

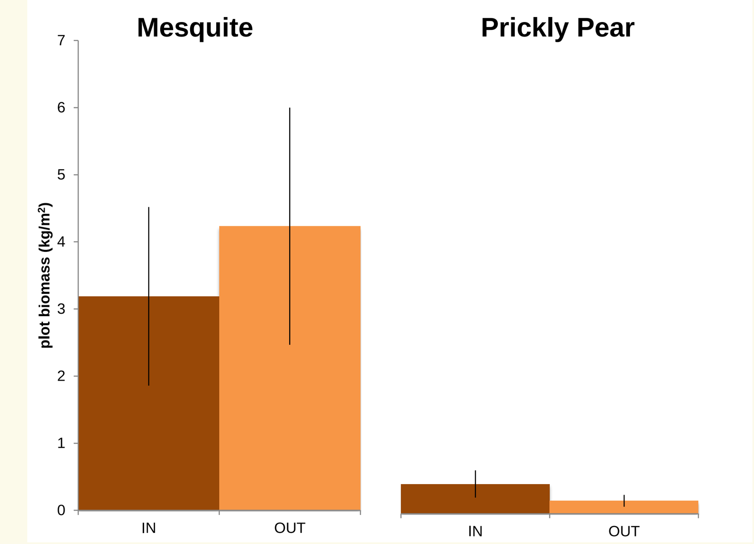

Figure 5: Mean (± SE) plot biomass (kg/m^2) was statistically comparable inside and outside the exclosure for both mesquite and prickly pear.

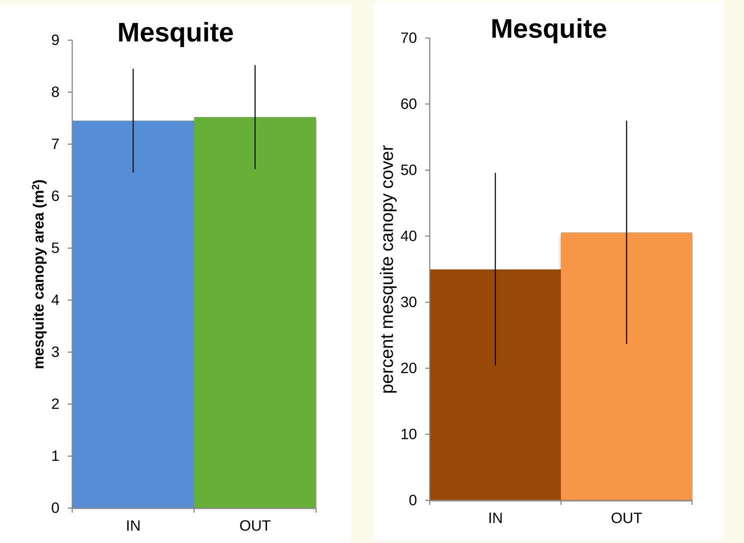

Figure 6: Mean (± SE) mesquite canopy area (m^2/plant) and percent canopy cover per plot was comparable inside and outside the exclosure.

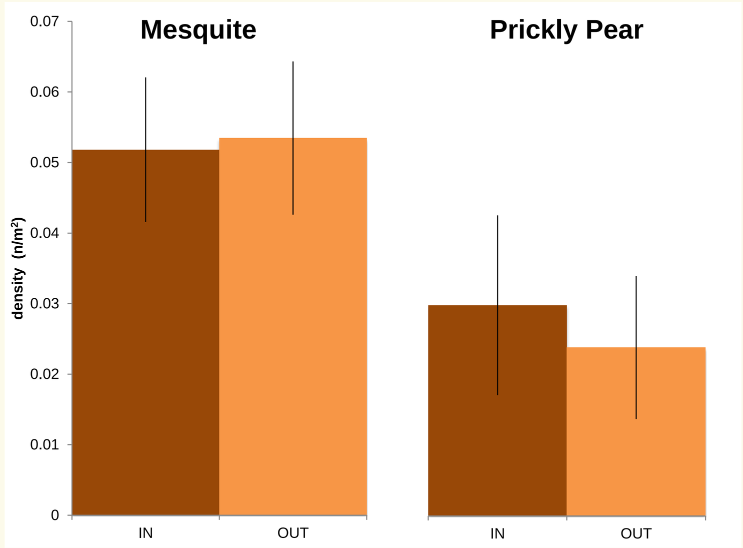

Figure 7: Mean (± SE) density (plants/m^2) was comparable inside and outside the exclosure for both mesquite and prickly pear.

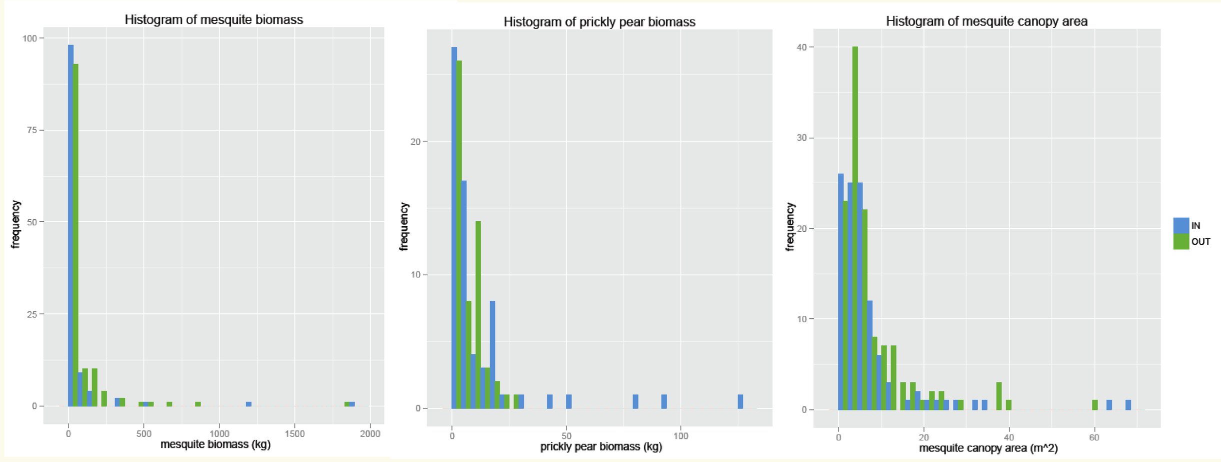

Figure 8: Histograms displaying plant-scale biomass and canopy area.

Discussion

- Mesquite and prickly pear cover have both increased on the SRER since the early 1900s (McClaran 2003). However, data from the *Eriopoda Exclosure* suggests that levels of livestock grazing have had little influence on this during the last 80+ years of mesquite and prickly pear increase.
- Results from this study are consistent with those comparing mesquite abundance in and out of the 70+ year old SRER *McGinnies Exclosure* (Browning and Archer 2011).
- Our results suggest a threshold for shrub encroachment had been reached prior to the exclusion of cattle from the site in 1925, after which grazing or protection from it has had little influence on the proliferation of mesquite and prickly pear
- The legacy of excessive grazing in the late 1800s and early 1900s coupled with lack of fire and, potentially, climate change has facilitated shrub establishment and growth for the past 100+ years.

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